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Many-body quantum quench in an atomic one-dimensional Ising chain

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Quantum tunneling is one of the most fundamental processes in nature. Single particle hopping of ultracold atoms in optical lattices changes its character dramatically when the ensemble is prepared in strongly correlated quantum phases due to atom-atom interactions. Correlated hopping in a Mott-insulating chain of bosons that is tilted to the Mott gap has recently been employed to study long-range order in the 1D transvers Ising model [1,2]. We study correlated tunneling dynamics for an ensemble of tilted 1D Mott chains after a sudden quench to the vicinity of the Ising paramagnetic to antiferromagnetic phase transition point [3]. The quench results in coherent oscillations for the orientation of effective Ising spins, detected via oscillations in the number of doubly occupied lattice sites. We characterize the quench by varying the system parameters. We report significant modification of the tunneling rate induced by interactions and show clear evidence for collective effects in the oscillatory response. We observe higher-order many-body tunneling processes over up to five lattice sites when the tilt per site is tuned to integer fractions of the Mott gap. Second- and third-order tunneling shows up in the transient response after the quench, from which we extract the characteristic scaling in accordance with perturbation theory and numerical simulations. In a second set of experiments we study the response of an ensemble of 1D superfluids in the Bose-Hubbard regime when subject to a tilt [4]. For large values of the tilt, we observe interaction-induced coherent decay and matter-wave quantum phase revivals of the Bloch oscillating ensemble. We analyze the revival period dependence on interactions by means of a Feshbach resonance. When reducing the value of the tilt, we observe the disappearance of the quasi-periodic phase revival signature towards an irreversible decay of Bloch oscillations, indicating the transition from regular to quantum chaotic dynamics.

[1] J. Simon et al., Nature 472, 307 (2011)
[2] S. Sachdev et al., Phys. Rev. B 66, 075128 (2002)
[3] F. Meinert et al., Phys. Rev. Lett. 111, 053003 (2013)
[4] F. Meinert et al., arXiv:1309.4045 (2013)

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